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On the Optimality of Interest-Bearing Reserves

in Economies of Overlapping Generations

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On the Optimality of Interest-Bearing Reserves in Economies of Overlapping Generations

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ABSTRACT: Paying interest on required reserves is considered in an overlapping generations model in which the return to capital dominates the return to fiat money. Smith (1991) showed that financing interest on reserves from lump-sum taxes benefits the initial old at the expense of future generations. Here, such a transfer of wealth is offset with an accommodating open market purchase so that interest on reserves is a Pareto improvement. With an accommodating open market sale, we show that abandoning reserve requirements results in identical utility for initial and future generations as paying interest on reserves. We also show that paying interest on reserves improves welfare even when financed by distorting taxes.

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The payment of interest on reserves held at the central bank has long been advocated [see, for example, Friedman's *A Program for Monetary Stability* (1960)]. Advocates note that the payment of a market rate of interest on required reserves eliminates the opportunity cost of holding those deposits that are subject to reserve requirements. In economies of infinitely lived representative agents, the distortion of reserve requirements is costlessly removed if these interest payments are funded through lump-sum taxes.

Smith (1991) demonstrates, however, that the payment of interest on reserves, even if financed through lump-sum taxation, actually reduces steady-state utility in economies of overlapping generations of finitely lived agents. The increased rate of return on deposits increases the demand for deposits and thus for reserves, lowering the price level and thus increasing the wealth of the initial owners of reserves. The taxes on future generations to finance interest on reserves thus effect a transfer of wealth from future generations to the initial generation. This loss of wealth makes future generations worse off despite the increased rate of return on deposits. Smith establishes the Pareto optimality of interest on reserves but warns that only the initial generation gains from financing interest through taxation, even if lump-sum.

In this paper, we establish that not paying interest on reserves is Pareto inferior; there is a way to recapture for the future generations benefits that accrue incidentally to the initial generation as a result of the payment of interest on required reserves, allowing a Pareto improvement. Following Auernheimer's (1974) prescription for "honest" seigniorage, we propose an open market purchase by the central bank that offsets the cahnge in money demand through an expansion of the monetary base, so as to leave unchanged the price level and the wealth of the initial generation.[1] The interest from the assets thus purchased by the central bank are used to help finance the payment of interest on reserves, reducing the taxation of future generations. We show that when financed in this way, the payment of interest on reserves results in a Pareto improvement, increasing the welfare of the future generations without hurting or helping the initial generation.

We go on to show that the elimination of reserve requirements accompanied by a similarly motivated open market sale of government debt can also result in a Pareto improvement. Steady-state utility is increased even after future generations are taxed to finance the interest on the government debt.

Finally, we demonstrate that financing interest through distorting taxes is still a Pareto improvement. We introduce a second type of capital, which is not subject to reserve requirements but which may be taxed. We then show that an equal tax on both forms of capital is Pareto improving when used to pay interest on reserves. This result demonstrates how reserve requirements distorts individual choices between intermediated and unintermediated capital. Spreading the tax across these two types of capital is in the spirit of the Ramsey Rule of efficient

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[1] This open market purchase has the same motivation as the open market sale proposed by Bacchetta and Caminal (1990) to offset intergenerational wealth transfers when a government financing expenditures from seigniorage reduces reserve requirements and increases the rate of money expansion.

taxation, so that even a distorting tax on two types of capital raises welfare compared to the case in which one is subject to a reserve requirement without interest.

1. Interest on Reserves

1.1 The Model

The model economy is Smith's (1991) version of the overlapping model with reserve requirements.[2] There is an infinite sequence of periods indexed by $t = 1, 2, 3, \ldots$. Agents live two periods. Within each period t, two generations coexist -- those in the first period of their life (the "young") and those in the last period of their life (the "old"). There are N agents born in each period $t \geq 1$. In the initial period, t=1, there are also N 1-period lived agents called the initial old. There exists two assets - fiat money and storage. Each of the initial old agents is endowed with a per capita stock of the storage good and fiat money balances, denoted k_0 and m_0, respectively. The initial old want as much of the consumption good in period 1 as possible.

Young agents have the twice continuously differentiable utility function: $U(c_1) + V(c_2)$, where c_i stands for consumption in the i^{th} period of an agent's life. It is further assumed that $U' > 0$, $V' > 0$, and $U'' \leq 0$, and $V'' < 0$.[3]To ensure an interior solution, U'(0) and V'(0) are assumed infinite. Each young agent receives an endowment of y units of the consumption good,

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2 See also Romer (1985), Sargent and Wallace (1985), and Freeman (1987).

3 The separability of the utility function is not essential to the arguments but we wish to follow Smith's assumptions and notation closely to facilitate comparison.

but nothing when old. The problem facing agents is how to finance consumption when old.

The two assets--fiat money and storage--offer different rates of return. When stored, the consumption good returns $x > 1$ units of the consumption good in period $t+1$ for each unit stored in period t. Because $x > 1$, we will interpret this storage option as equivalent to capital. The initial old own M_0 ($= Nm_0$) units of fiat money. Fiat money is intrinsically useless and noncounterfeitable. The young can trade a unit of the consumption good for p_t units of fiat money. In period $t+1$, the old (the young of period t) trade each unit of fiat money for $1/p_{t+1}$ units of the consumption good. Thus, the rate of return to fiat money balances held by the initial old is p_t/p_{t+1}.

Each young agent is required to hold a fraction γ of his total real savings Q_t in reserves of fiat money:

(1) $$z_t \geq \gamma Q_t.$$

In every period after the initial period, required reserves pay ρ units of fiat money in net interest for each unit held in required reserves. Thus for $t > 1$, the real return to a required unit of fiat money is $p_t(1+\rho)/p_{t+1}$ (but only p_t/p_{t+1} if held beyond the level required). A lump-sum tax of τ units of the consumption good is collected from each old agent. Except for the initial old, the lump-sum tax revenues are then used to pay interest on required reserves.[4]

In addition to collecting taxes and paying interest on reserves, we will allow the

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[4] We could also tax the old in the initial period in order to pay interest on the initial fiat money stock. This would be a lump-sum tax to pay an equal lump-sum benefit. We ignore the possibility because it would have no real effect.

government to expand the money supply from M_0 to M in order to purchase and store K_g goods in the initial period.[5]

1.2 Equilibrium conditions

Each young agent born at *t* chooses his personal savings Q_t, taking taxes and the real gross return on savings (call it R_t) as given, to maximize $U(c_1) + V(c_2)$ subject to equation (1), along with the following budget constraints

(2) $$c_1 + Q_t = y$$

(3) $$c_2 = R_t Q_t - \tau_{t+1}$$

The first-order condition for this program is

(4) $$U'(y-Q_t) = R_t V'(R_t Q_t - \tau_{t+1}).$$

We focus our attention on those cases in which the reserve requirement constraint is binding; that is, $x > p_t/p_{t+1}$. When $z_t = \gamma Q_t$, the return to the agents portfolio is a weighted average of the return to capital and to money:

(5) $$R_t = (1-\gamma)x + \gamma(1+\rho)p_t/p_{t+1}$$

The clearing of the market for fiat money requires

(6) $$M = p_t \gamma N Q_t.$$

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[5] The government's capital purchases are equivalent to a case in which the government has outstanding government debt and uses the expanded money supply to retire some part of the debt.

In an equilibrium with real saving equal to a constant Q, the price level p will also be constant and the rate of return to savings will be the constant

$$R = (1-\gamma)x + \gamma(1+\rho) . \tag{7}$$

The government budget constraint in the initial period requires that the proceeds of the open market purchase be used to purchase government capital:

$$K^g = [M - M_0]/p \tag{8}$$

In subsequent periods government revenues include the net return on storage/capital (gross value less replacement costs) plus the lump-sum tax on the old. Expenses are the interest payments on reserves. Formally, in a stationary equilibrium

$$(x-1)K^g + N\tau = \rho M/p . \tag{9}$$

In short, a stationary equilibrium is a vector (Q, R, p) that depends on a policy vector (K^g, ρ, τ) such that all the equilibrium conditions equations (2)-(9) are satisfied and equation (1) holds with strict equality.

1.3 Equilibria without open market operations

Smith considered government policies without open market operations ($K^g = 0$), comparing in particular a policy of no interest on reserves ($\rho = 0$) with a policy of paying the market interest on reserves ($\rho = x-1$).

When no interest is paid on reserves, $R = \hat{R} = (1-\gamma)x + \gamma$ and the resulting equilibrium level of savings $\hat{Q}$ is given by[6]

$$(10) \qquad U'(y - \hat{Q}) = RV'([\,(1-\gamma)x + \gamma\,]\,\hat{Q}).$$

From (6), the equilibrium price level is $\hat{p} = M_0/\gamma N \hat{Q}$.

When the market rate of interest is paid on reserves and financed entirely through taxes on the old, we have that $\rho = x-1$ and $\tau = \rho M_0/p^*$, where p^* is equal to M_0/NQ^* and Q^* satisfies

$$(11) \qquad U'(y-Q^*) = xV'([xQ^* - \tau).$$

$$= xV'([xQ^* - (x-1)\gamma Q^*)$$

Smith demonstrates that paying interest on reserves encourages savings ($Q^* > \hat{Q}$), thus increasing the demand for reserves, lowering the price level ($p^* < \hat{p}$).[7] Smith's Proposition 3 establishes that all generations except the initial old are worse off when interest is paid on reserves and financed in this way. The initial old are better off with interest paid on reserves because the the lower price level increases the value of their initial fiat money balances. The two equilibria are therefore not Pareto comparable.

1.4 Equilibria with open market operations

The initial old benefit from the payment of interest on reserves but only later

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[6] Our γ equals $1-\phi$ as ϕ was defined by Smith.

[7] The wealth effect of the increased rate of return is exactly offset by the taxes required to pay the interest, leaving only a substitution effect.

generations are asked to pay for it under the financing just described. This intergenerational transfer of wealth raises an obvious question – why are all future generations are worse off? Is it because interest-bearing reserves are inefficient or because they have transferred wealth to the initial generations? To resolve this question we must look for a method of financing the interest on reserves that doesn't transfer wealth to the initial generation.

The answer involves an *open market purchase* – a purchase of assets from an expansion of the initial fiat money stock to offset the increased demand for reserves. The interest from assets thus acquired will be used to lower future taxes. We examine in particular an *accommodating* open market purchase -- one that leaves the price level where it would have been in the absence of a change in reserve policy.

The clearing of the market for fiat money requires that

(12) $$p_t = M/\gamma Q_t$$

If the government pays interest on reserves, the demand for savings (Q_t) rises, lowering the price level. To prevent a transfer of wealth to the initial generation, let us increase M to maintain price level at $\hat{p} = M_0/\gamma N\hat{Q}$, its value when no interest is paid on reserves. Doing so requires that M satisfy

(13) $$\hat{p} = M_0/\gamma N\hat{Q} = M/\gamma NQ \quad \text{or}$$

(14) $$M = M_0 Q/\hat{Q}$$

The increase in the fiat money stock, $M - M_0 = M_0(Q/\hat{Q} - 1)$, will be used to finance the government's purchase of capital worth (the storage of)

$$K^g = M_0(Q/\hat{Q} - 1)/\hat{p} \tag{15}$$

The net proceeds from this capital/storage, $(x - 1)K^g$, will be used along with lump-sum taxes on the old to finance future interest on reserves at the rate ρ. The government budget constraint (9) can now be written as

$$(x-1)M_0(Q/\hat{Q} - 1)/\hat{p} + N\tau = \rho M/\hat{p} \tag{16}$$

We are now ready to demonstrate the Pareto inefficiency of not paying interest on reserves.

Proposition 1: Steady-state utility is maximized by paying the market rate of interest ($\rho = x$-1) on reserves when financed by lump-sum taxes on the old and an accommodating open market purchase.

Proof: The proof proceeds in two steps. First, we derive the tax level necessary to finance interest payments on reserves, taking into account the open market purchase needed to offset the change in the real demand for reserves. Second, given the policy constraints we find steady-state utility as a function of Q and determine the Q that maximizes steady-state utility. We then find the rate of interest on reserves that, in equilibrium, will lead agents to choose this utility maximizing Q.

Using the market clearing conditions $M_0/\hat{p} = \gamma N\hat{Q}$ and $M/\hat{p} = \gamma NQ$, we can find the following reduced-form expression for taxes:

(17) $$\tau = (\rho + 1 - x)\gamma Q + (x-1)\gamma\hat{Q} .$$

Recall from (7) that the rate of return on savings in a steady state is

$$R = (1-\gamma)x + \gamma(1+ \rho)$$

Together, (3), (7), and (17) permit us to find $c_2 = R\,Q - \tau$, or

$$c_2 = [(1-\gamma)x + \gamma(1+ \rho)]Q - [(\rho + 1 - x)\gamma Q + (x-1)\gamma\hat{Q}]$$

which after some simplification of terms is

(18) $$c_2 = xQ - (x-1)\gamma\hat{Q}$$

Steady-state utility can now be expressed as a function of Q:

(19) $$U(y - Q) + V(xQ - (x-1)\gamma\hat{Q})$$

Steady-state utility is maximized when

(20) $$U'(y - Q)/V'(xQ - (x-1)\gamma\hat{Q}) = x$$

From (4) and (7), this condition is met in equilibrium if and only if reserves pay the market rate of interest, *i.e.*, if $1 + \rho = x$. *Q.E.D.*

The intuition behind the proposition is fairly straightforward. Only when the marginal rate of substitution equals the rate at which goods can be transformed into future goods can the level of savings be optimal.

Smith found that interest reduced the utility of future generations because it increased the value of the reserves, providing a transfer to the initial generation funded by the taxes of future generations. Once the initial generation is taxed through the expansion of the money stock to offset this benefit, future generations benefit unambiguously. With an open market purchase of exactly the size that maintains the initial value of fiat money balances, there is no transfer from the future generations to the initial old. (Note the feature of this policy that the government can determine the correct size of the open market operation by targetting price stability.) By purchasing capital with the increase in the fiat money stock, the incidental benefit to the initial generation is now taxed to help finance the interest on reserves. Without the wealth transfer to the initial old, future generations are no longer made worse off by paying interest on reserves. Our results, therefore, confirm that it is the transfer of wealth that is responsible for Smith's Pareto non-comparability result.

2. Eliminating Reserve Requirements

A more straightforward way to increase the rate of return to saving is the simple abandonment of reserve requirements. This action alone benefits future generations at the expense of the initial generation, whose initial balances of fiat money become worthless (for $x>1$). Therefore, the elimination of reserve requirements can only be shown to be a Pareto improvement if the initial generation can be compensated for their loss. We will show that an open market sale of government debt in exchange for the initial reserves [proposed by Auernheimer (1974) and Bacchetta and Caminal (1990) in related contexts[8]] can compensate the initial generation, yet leave future generations better off from the elimination of reserve requirements. In particular we will show that the elimination of reserve requirements is the welfare equivalent of paying interest on reserves when both are accompanied by accommodating open market operations.

Proposition 2: The elimination of reserve requirements, with an accommodating open market sale, has the same effect on steady-state utility as paying market interest on reserves with an accommodating open market purchase.

Proof: To demonstrate this equivalence, first we show that the rate of return is identical when paying interest on reserves and removing reserve requirements. Second, we show that consumption by the future generations is unchanged.

Establishing the equality of the rates of return is trivial. Clearly, from equation (5), setting $\gamma = 0$ results in $R_t = x$. With the identical rate of return, it is obvious that the marginal rate of substitution equals the rate at which consumption goods in period 1 can be transformed into consumption goods in period 2. Thus equation (20) holds for the case in which reserve

8 Auernheimer (1974) studied changes in rates of money creation. Bacchetta and Caminal (1990) studied the reduction of reserve requirements used to finance a fixed level of government expenditures.

requirements are removed.

Removing reserve requirements means that the initial old cannot use the reserves to consume in period 1. The value of the lost consumption is $\gamma\hat{Q}$. To replace the lost consumption for the initial old, the government issues a permanent debt B equal to

(21) $$B = N\gamma\hat{Q}.$$

The government also sets a lump-sum tax in each period $t > 1$ to finance the net interest on this government debt. As before, the lump-sum tax is paid by the old of the future generations. Thus, $N\tau = (x-1)B$. Using equation (21), the level of taxes (per old agent) necessary to finance the interest payments can be written as

(22) $$\tau = (x-1)\gamma\hat{Q}.$$

Steady-state consumption when old by the future generations is $c_2 = R\,Q - \tau$. Substituting the rate of return when reserve requirements are removed and equation (22) in the expression for second-period consumption yields

(23) $$c_2 = xQ - (x-1)\gamma\hat{Q}.$$

Note that equation (23) is identical to equation (18). Thus, steady-state utility, expressed as function of Q, for the case in which reserve requirements are removed with an accommodating open market sale is equivalent to the case in which the government pays interest on reserves, financed through lump-sum taxes and an accommodating open market purchase. *Q.E.D.*

If reserve requirements are removed, the initial old's fiat money balances become worthless, the price level infinite. The transfer from the initial old generation to future generations when reserve requirements are removed is exactly the same as the transfer from future generations to the initial old when interest-bearing reserves are introduced. An accommodating open market operation leaves the initial old generation just as well off as before the policy experiment is conducted, leaving future generations to gain from the higher rate of return even after financing the compensation of the initial old.

3. Distorting Taxes

The analysis above depends on lump-sum taxes for the financing of interest payments. Real world governments, however, are apparently constrained to distorting taxes. Should one still advocate the payment of interest on reserves when that interest must come from distorting taxes? The answer will depend on what is taxed to pay interest. If assets subject to reserve requirements (storage in this model) are taxed at a constant marginal rate in order to make proportional interest payments on reserves, the after-tax rate of return is not changed by the payment of interest. Certainly, however, intermediated deposits are not the only taxable quantity. Let us therefore introduce another taxable economic variable in order to inquire as to whether distorting taxes on another variable should be introduced to reduce the distortion imposed by interest-free required reserves.

In addition to the storage technology, let there be a capital technology of this form: an investment of any positive k_t goods in period t by any individual will produce $f(k_t)$ goods in period t+1. It produces in no other period. The function f(.) is continuously differentiable, increasing, and concave with $f'(0) = \infty$ and $f'(y) < x$. We assume that storage is only possible in amounts greater than an individual's endowment y. Agents are thus only able to store through intermediaries that pool the endowments of many agents. As before, a reserve requirement is imposed on storage (intermediated deposits) but not on capital (which requires no intermediation).[9]

We will confine our attention to steady-state equilibria in which both storage and capital are positive. Let Q represent intermediated deposits, K unintermediated capital, and S total savings per young person (implying that S = Q + K). As before, equilibrium values of variables in the absense of interest on reserves will be marked by a carrot (^). The first order maximization conditions with respect to the individual's choice of deposits and unintermediated capital in the absence of interest are respectively

$$(24) \qquad U'(y - \hat{Q} - \hat{K}) = [\,(1-\gamma)x + \gamma\,]\, V'([\,(1-\gamma)x + \gamma\,]\,\hat{Q} + f(\hat{K})\,)$$

$$(25) \qquad U'(y - \hat{Q} - \hat{K}) = f'(\hat{K})\, V'([\,(1-\gamma)x + \gamma\,]\,\hat{Q}) + f(\hat{K})\,)$$

which together imply

$$(26) \qquad f'(\hat{K}) = [\,(1-\gamma)x + \gamma\,] < x$$

The payment of interest on reserves will be financed by a tax of α times the return from

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9 The reason for the existence of intermediation is unimportant to our results. It is only important that there are two forms of productive assets, one of which is subject to reserve requirements.

any asset ($0 \leq \alpha \leq 1$). The government will also engage in an open market operation that maintains an unchanged price level. The government must finance net interest on reserves of $(x-1)\gamma(S - K)$ from taxes on the return from savings, $\alpha x(S - K) + \alpha f(K)$ and from the interest on the capital it acquires from the open market purchase in the initial period, $(x-1)\gamma[(S - K) - (\hat{S} - \hat{K})]$. Altogether this implies that

$$(27) \qquad (x-1)\gamma(S - K) = \alpha x(S - K) + \alpha f(K) + (x-1)\gamma[(S - K) - (\hat{S} - \hat{K})]$$

or

$$(28) \qquad (x-1)\gamma(\hat{S} - \hat{K}) = \alpha x(S - K) + \alpha f(K)$$

The individuals first-order maximization conditions with market interest paid on reserves may be summarized as:

$$(29) \qquad U'(y - Q - K) = x(1-\alpha) V'(x(1-\alpha)Q) + (1-\alpha)f(K)) \qquad \text{and}$$

$$(30) \qquad x = f'(K) .$$

Proposition 3: Payment of the market rate of interest ($\rho = x-1$) on reserves increases steady-state utility when financed by a linear tax on the return from all assets and an accommodating open market purchase.

<u>Proof</u>: The proof establishes that total net return is greater when the government pays interest on required reserves, financing these expenditures through an accommodating open market purchase

and linear capital taxes than when there is no interest on reserves.

Paying interest on reserves makes future generations better off if for any given level of savings, $S = S^*$, the total return net of taxes is greater when interest is paid on reserves:

$$(31) \qquad (1-\alpha)x(S-K) + (1-\alpha)f(K) > -[x(1-\gamma)+\gamma](\hat{S}-\hat{K}) + f(\hat{K})$$

We can now use the government budget constraint (28) to cancel several of the tax terms with terms on the right hand side of (31) leaving us with

$$(32) \qquad -xK + f(K) > -x\hat{K} + f\hat{K})$$

or

$$(33) \qquad x(\hat{K}-K) > f(\hat{K}) - f(K)$$

We know that $\hat{K} > K$ because unintermediated capital is taxed when interest is paid on reserves. With f(.) as a concave function (capital has a diminishing marginal product), the Mean Value Theorem implies that

$$(34) \qquad f'(K)(\hat{K}-K) > f(\hat{K}) - f(K)$$

When interest is paid on reserves, we know from (30) that the two forms of capital must offer the same marginal rate of return, i.e., $f'(K) = x$. It follows that the inequality (33) is satisfied, proving that future generations are better off with interest paid on reserves even if it must be financed through a distorting capital tax. *Q.E.D.*

At first glance Proposition 3 may be counterintuitive; interest payments introduce a distortionary tax where there was none before. The explanation is that reserve requirements without interest payments act like a distorting tax even if they raise no revenue. The existence of a second type of capital, not subject to reserve requirements, is important for this result. Interest financed by taxes spreads the distortion introduced by reserve requirements across both intermediated and unintermediated capital. In this sense, the linear tax on capital improves welfare for essentially the same reason that the Ramsey Rule for efficient taxation is welfare improving.

4. Summary and Conclusions

This paper shows that Friedman's proposal to pay interest on reserves maximizes steady state welfare, assuming that the burden is financed with lump-sum taxation and accommodating open market purchases. This result modifies the Pareto non-comparability result presented in Smith.

We further show that abandoning reserve requirements is equivalent to paying interest on reserves, provided that the initial old are compensated. This compensation is financed by an open market sale of bonds whose interest is funded from lump-sum taxes.

The accommodation schemes considered here are often observed. There is evidence that central banks routinely offset changes in reserve policies with open market operations. Muelendyke (1991) asserts that the Federal Reserve smooths the effects of changes in reserve requirements. Using different measures of changes in reserve requirements, Haslag and Hein (1989, 1993) provide evidence suggesting that the Federal Reserve systematically accommodates decreases in reserve requirements, for example, letting the quantity of high-powered money fall.

Finally, we demonstrate that interest payments on reserves results in higher steady-state welfare (given an accommodating open market purchase) even if financed with a distortionary tax applied against capital. It is important that distortionary tax is applied to unintermediated capital, as well as intermediated capital, which underscores the distortion imposed by reserve requirements. In short, spreading a distortion across the two types of capital is more efficient than distorting only intermediated capital.[10]

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[10] It should be noted that the policy implications of this paper apply to all forms of fiat money, not just reserves. The commonly imposed prohibition on the issuance of private currency is in essence a reserve requirement of 100%. Dropping this prohibition or paying interest on fiat currency will thus also result in a Pareto improvement when accompanied by an accommodating open market operation.

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